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Military Vehicle Testing

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U. S. Army Test and Evaluation Command

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SOCIETY OF AUTOMOTIVE ENGINEERS

International Automotive Engineering Congress
Detroit, Michigan
January 11-15, 1965

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THE U. S. ARMY Test and Evaluation Command is a relatively new organization of the Army and was activated in August, 1962. Studies made prior to the Army's reorganization reported duplication of testing, inadequate testing in some instances, and too much testing in others, and indicated a general lack of test coordination. The consolidation of all separate major test activities into one command was aimed at eliminating these deficiencies and at providing the Army with a sound materiel test program that would provide dependable evaluations in a minimum of time. The accomplishment of these objectives is not a small task nor an easy one. Some progress has been made. Much is yet to be accomplished.

This paper, by covering the subject, "Military Vehicle Testing," provides a brief insight into the organization, functions, and hopes of this new command. In addition, the processes of test planning, types of test considered essential, facilities used, and the ever important phase of evaluating test results are discussed.

THE TEST ORGANIZATION

The Test and Evaluation Command, a major element of the U.S. Army Materiel Command, has its headquarters located at Aberdeen Proving Ground, Maryland. Overall, it is composed of 19,000 personnel, both military and civilian, located at eight proving grounds and ranges, six service test boards, and three environmental test centers. Since military equipment must be designed to operate worldwide under all terrain and climatic conditions, test sites are located from the cold regions of Alaska to the tropics of Panama (Fig. 1). In between these areas lie heat and sand, swamps and mud, rivers and lakes, plains and mountains, against which military equipment is pitted.

The mission of TECOM, as it is commonly called, is to provide impartial and independent tests and evaluations of equipment proposed for military use. While the approved

nomenclature test list identifies 19 test types conducted by the Test and Evaluation Command, for practical purposes they can be consolidated into two general groups:

1. Engineering (technical) and service (military oriented) tests, which are conducted on all new materiel to determine its suitability for Army use prior to production.

2. Those tests conducted as a service to developing commodity commands and project managers. Such tests may involve evaluation of new ideas for military potential, gathering of design test data on experimental components under field test conditions, or spot checking production materiel to ensure that adequate standards of quality are being maintained by the manufacturer.

RATIONALE FOR TESTING

Test is an integral part of research, development, and production processes. It is not an end in itself, but a measure of product correctiveness, suitability, and quality. Efficient testing must have the characteristics discussed below.

OBJECTIVE - As a rule, the test engineer should be independent from the designer. It is against human nature for one to criticize his own handiwork. Being objective does not mean that the experience and judgment of qualified persons are not necessary in test planning and in evaluation of results. Rather, test design must be oriented toward producing meaningful and factual data, eliminating inherent tendencies of personal bias.

REALISTIC - Test emphasis must be within the realm of the vehicle's mission. That is, tests on a cargo truck should be primarily geared toward determining that it will properly haul cargo (and special loads) under prescribed terrain and environmental conditions. The 1% problems, that is, seeking out a circumstance seldom found in nature, should be avoided.

ABSTRACT

One purpose of the Army's reorganization in 1962 was to consolidate and streamline testing of its materiel. Objectives of the Army's new test organization, the Test and Evaluation Command, are briefly discussed. The scope of

testing on military vehicles, including test planning, type of tests conducted, facilities used, and reporting procedures, are outlined. Evaluation of test results is compared against military requirements.

SOUND - Tests results must withstand critical review and therefore the objective of testing is evaluation. It is essential in test design that full consideration be given to the accumulation of adequate data to permit valid evaluation. Design inadequacies must be positively identified; isolated failures must be deemphasized. Unfortunately, because of monetary and time reasons, sample sizes are often too small and data too limited for total analysis. Reports, then, should identify where confidence levels of results are low.

TIMELY - To be effective in contributing to redesign during the development process, testing must be timely. Test time must be held to a minimum consistent with development objectives. Early planning, sufficient test models, participation of test personnel in early design discussions, full utilization of research and design test data, adherence to the principle of joint testing where practicable, and full exchange of test data among all participating test agencies are some of the means for reducing test time.

Most important is the elimination of unnecessary duplication in testing. "It wasn't tested here" and "testing for testing sake" must go. On the other hand, testing must not be arbitrarily eliminated or shortened just to meet preconceived deadlines. Premature production leads to untold production, training, and logistical support difficulties.

TEST PLANNING

Starting with the foregoing generalities, let us narrow the field of testing to manageable proportions and develop

a test plan on a typical military vehicle such as a cargo truck. Test planning follows four principal phases.

REVIEW OF MILITARY CHARACTERISTICS - Just as the designer must understand the Qualitative Military Requirements established for a new vehicle and translate these requirements into engineering terms against which he can design, the tester must understand the requirements and translate them into terms against which he can test.

The first step in good test planning, then, is to review and understand the military requirements. The planner must question, "Can a test be designed to prove that each required military characteristic is met?" For example, "Operate on a dry, level concrete road at 50 mph" is easy. "Possess improved cross-country mobility over the current standard truck" takes some real thought and effort. "Shall operate with minimum practicable maintenance" is not really testable.

COORDINATED TEST PROGRAM - After review and resolution of questionable areas in the Qualitative Military Requirements, a Coordinated Test Program is prepared by the Test and Evaluation Command. This document reflects early test planning on the basic vehicle and its associated kits, and serves as a guide to all participating agencies in planning, scheduling, and funding test activities.

The CTP provides a basis for establishing prototype requirements, alerts test agencies to the need for unusual test facilities, and outlines the broad test objectives of each test agency. Fig. 2 is a typical phasing schedule from such a Coordinated Test Program, which will be discussed in more

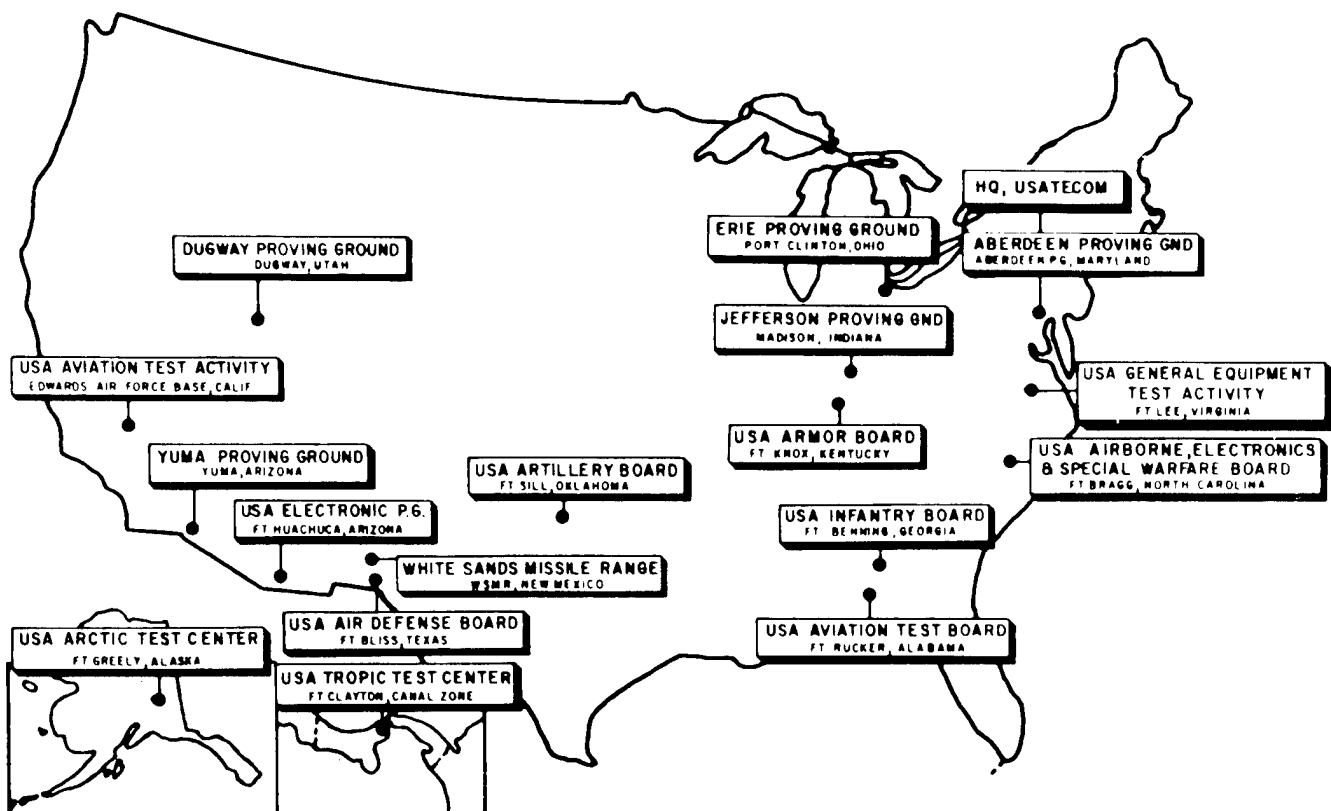


Fig. 1 - Test installations of USAFTECOM

detail later under "Scope of Tests." It is of primary importance to the Test and Evaluation Command at this point in the planning cycle to ensure that sufficient prototype vehicles are being made available to:

1. Permit concurrent testing by the primary engineering and service test agencies.
2. Accomplish the arctic, desert, and tropic environmental test phases on a year-round basis prior to type classification.
3. Provide for movement adaptability (suitability for movement by highway, ship, rail), logistics over the shore (off loading from seagoing vessels, landing craft), and air transportability trials prior to production release.
4. Establish inputs by principal using arms (Infantry, Artillery, Engineer, and Marine Corps) before the production configuration becomes too firmly fixed.
5. Provide a sound basis for decision making on reliability and durability, that is, the accumulation of up to 150,000 test miles under assorted terrain conditions.

DETAILED TEST PLANS - The next step in overall test planning involves the preparation of the detailed test plans. While the Coordinated Test Program outlines the broad test objectives of each proving ground and service test board, the plans of test reflect in detail how each test objective will be met. For example, when examining a typical engineering test procedure for endurance and reliability we find:

1. Purpose: Determine if the test truck is capable of meeting the following military characteristics:

(a) Durability: The vehicle shall be capable of operating in a military environment for 10,000 miles with only organizational maintenance (1st and 2d echelon) and without failure of accessories or integral major assembly; also, an additional 10,000 miles without maintenance beyond the

direct support echelon (3rd) or the replacement of a major assembly.

(b) Reliability: Shall be adequate during the first 10,000 miles so that the time required to correct unexpected part failures and vehicle breakdowns will not exceed 25% of the time required for preventive maintenance. For 20,000 miles, the maintenance will be the minimum practicable, but must not exceed 500 man-hours for all maintenance.

2. Method

(a) Two test trucks and one present standard truck of the same weight class will be operated for 20,000 miles. The mileage shown in Table 1 will be accomplished in eight cycles of 2500 miles each over the various courses. Generally, the operation conditions are divided to achieve 30% on primary roads (highways), 40% on secondary roads, and 30% on cross-country under varying weather conditions (dust, mud, freezing) occasioned by seasonal changes.

(b) Approximately 50% of the miles over each course during each cycle will be run with towed load (at least 50% of gross vehicle weight) when practical, and the last cycle (8th) must be run without payload or towed load. Vehicle road speed during the 2nd and 7th cycles will be limited to a maximum of 35 mph, to simulate convoy road speeds.

(c) One of the test vehicles will use CITE (compression ignition turbine engine) fuel throughout the test. The second will run 50% CITE, 25% diesel, and 25% gasoline.

COORDINATED PLAN OF TEST - Each objective in the test plans is similarly detailed and all plans are forwarded to the Test and Evaluation Command for approval. At this time, the individual plans are given close review and consolidated into a single overall Coordinated Plan of Test. This is designed to ensure that:

1. Test design is complete and that there are no omissions in test scope and coverage.
2. Unnecessary tests are eliminated.
3. Duplicate testing, if present, is justifiable.
4. Allotted test time is realistic in view of objectives and outlined procedures.

Approval and distribution of the Coordinated Plan of Test completes the planning cycle. Test agencies are ready for the prototype trucks to arrive, and each agency knows what to do and how to do it.

SCOPE OF TESTS

It is necessary now to go back to Fig. 2, a typical phasing schedule, and examine the scope of testing on a military truck.

First and of major importance to the overall success of the development program is the fabrication and test of test rigs. Test rigs are early, first generation models which represent as nearly as possible the final prototype configuration. Rigs are tested on an accelerated basis at either the contractor's plant or an Army proving ground, or both, to uncover at an early date the major design weaknesses.

These first tests are broad in scope and briefly examine

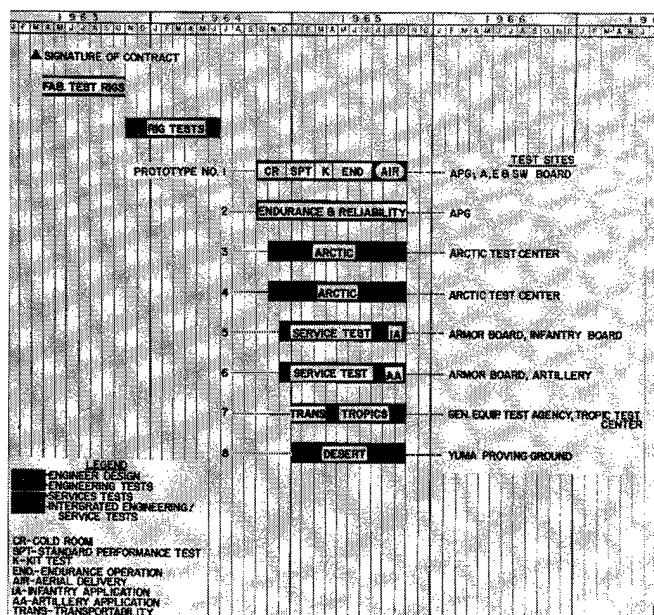


Fig. 2 - Phasing schedule of typical cargo truck

Table 1 - Test Setup

Miles	Per- cent	Type Course	Description
750	30	Paved	3 mile bituminous concrete straightaway with 1/4 mile turns at each end.
325	13	Improved gravel	2 mile closed loop of well-maintained gravel road with both sharp and sweeping turns.
575	23	Unimproved gravel	A 2.5 mile closed loop of poorly maintained gravel road with moderate washboarding and cutting and occasional potholes. Level, with sharp and sweeping curves.
100	4	Belgian block	A 0.75 mile course of typical cobblestone surface. Level, with few turns.
325	13	Hill cross-country	4 mile loop with clay and stone surface. Frequent grades to 30%, with both sharp and sweeping turns. Mud condition varies from light to sticky and cohesive. Little free water. Dust conditions severe in dry weather. Course maintained to hold surface conditions reasonably constant.
160	13	Level cross-country	Three specific courses, with varying degrees of severity, with free water, mud, and frequent turns.
25	1	Swamp	A tract of generally level but severe undulating terrain of low elevation. Surface conditions vary from dry solid earth to wet, soft, spongy areas. Characteristic of a marsh in that areas are inundated with water and primary growth is grass and cattails.
75	3	Sand	Accomplished at an ocean beach on both hard-packed sand and in the dune areas.
1 (hr)		Water	Swimming operation.

all areas of required performance. As much durability mileage as time permits is accumulated. Based on these tests, design corrections can then be applied to the prototype configurations scheduled for delivery to the Army for evaluation.

Don't underestimate the value of test rig testing. Seldom is a "first generation" vehicle acceptable; "second generations" stand a fair chance; "third generation" designs usually conform to stated requirements.

Prototype vehicles are usually delivered (with kits) to the Test and Evaluation Command agencies over a three to four month period. In Fig. 2, prototypes 1 and 2 are shown shipped to the Aberdeen Proving Ground for engineering tests, the technical side of testing. Prototype 1 initially undergoes cold chamber studies to determine low temperature starting characteristics and other extreme winter problems down to -65 F. These tests are given first priority to obtain needed data prior to delivery of Prototypes 3 and 4 to the Arctic Test Center for tests under the actual and more brutal arctic field conditions.

Following cold room appraisal, the instrumented Prototype 1 undergoes Standard Performance Test (SPT), which includes measurements on braking, steering, acceleration, drawbar pull, power losses, grade and slope performance, fuel consumption, swimming speed and stability, and mobility (Fig. 3).

Additionally, a cooling survey is made on the engine, transmission, and differentials to ensure that the vehicle has a reasonable chance of cooling under actual desert temperatures. Further, the assorted kits, such as cal .50 machine gun, winch, and shelters, are installed and studied. Human engineering factors are checked. Operation of the truck is accomplished over standard obstacles such as vertical walls, trenches, and the frame twister course (Fig. 4).

After these tests, the truck is placed on endurance and reliability testing prior to its delivery to the Airborne, Electronics, and Special Warfare Board at Fort Bragg, North Carolina, for air transportability and parachute delivery trials. In these tests, loading, restraining, and off-loading from appropriate aircraft are studied. The truck, if required by military characteristics, is rigged and parachute dropped (Fig. 5). External transport by helicopter is also accomplished when appropriate.

In the meantime, Prototype 2 has been placed immediately on a 20,000 mile endurance and reliability test. All failures are analyzed as to type and cause so that correc-



Fig. 3 - Drawbar pull measurements with field dynamometer

tive design actions can be undertaken. Detection of a failure without isolation of cause provides little assistance to the designer in overcoming his problems. For this reason, much emphasis is given to failure isolation during engineering tests using instrumentation, as required.

Prototypes 3 and 4 are shipped to the Arctic Test Center, Fort Greely, Alaska, for arctic environmental tests under year-round conditions. These tests, while primarily service in nature, combine engineering and service test objectives which include cold starting, vehicle warm-up times, snow mobility, and adaptability of the arctic kits (Fig. 6). The winter season at Fort Greely is normally at its best for test purposes from November through March (see Table 2).

Cross-country operation in the arctic is more difficult in the warm season when the ground surface is not frozen.



Fig. 4 - Frame twister course

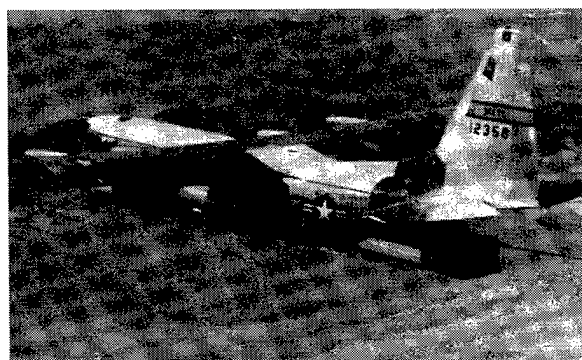


Fig. 5 - Parachute delivery of 35,000 lb load

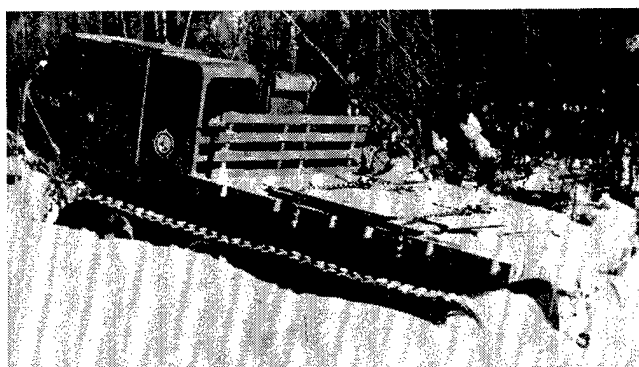


Fig. 6 - Exposure of military vehicle to arctic environment

Year-round testing provides the opportunity to study mobility over soft muskeg and tundra, to examine swimming in the braided type rivers of the arctic, and to accumulate endurance and reliability data under assorted arctic terrain conditions.

Prototypes 5 and 6 are delivered to the U.S. Army Armor Board, Fort Knox, Kentucky, for basic service testing. The service test is characterized by qualitative observations and judgments of selected military personnel having a background of field experience with the type of material undergoing test (Fig. 7). The test employs soldiers representative of those who will operate and maintain the equipment in the field.

In these tests, evaluation of the maintenance package (tools, maintenance procedures, and manuals) and compat-

Table 2 - Big Delta, Alaska Environment (1)*

Month	Temperature - F (mean daily minimum)	Mean Snow, Depth, in.	Mean Wind, mph
Jan.	-13	10.7	17.0
Feb.	- 7	17.0	17.0
Mar.	1	14.9	10.0
Apr.	18	11.6	9.0
May	36	9.6	10.0
June	46	2.0	9.0
July	49	0.0	8.0
Aug.	44	0.0	10.0
Sept.	36	Trace	10.0
Oct.	20	4.2	13.0
Nov.	- 2	7.0	15.0
Dec.	-13	10.5	14.0

*Numbers in parentheses designate References at end of paper.



Fig. 7 - Service testing examines soldier-machine compatibility

ibility of the soldier and machine are given emphasis. Overall, by Army Regulation, it is results of the service test that are given much weight in final determination of the equipment's suitability for Army use.

The service test includes evaluation of road and cross-country mobility; fuel and oil consumption under typical terrain conditions; compatibility of the truck with related equipment such as towed loads, cargo loads, wreckers, and recovery vehicles; and security of the vehicle from enemy detection. Further, swimming tests are conducted in rivers having assorted entrance and exit slopes and varying water velocities (Fig. 8).

Stowage of "on vehicle equipment" is examined for location, accessibility, and protection during all phases of vehicular operation. Kits are installed, checked for compatibility, and removed by crewmen at first and second echelon level. Additionally, each truck is operated to 20,000 miles, adding to the overall data bank on durability and reliability.

Prototype 6, at completion of the service test, is sent to the U.S. Army Infantry Board, Fort Benning, Georgia, for branch application tests. In these tests, the Infantry Board works closely with the Infantry School and Infantry Combat Developments Command Agency in evaluating vehicle features that are of major importance to infantry tactical operations. For example, the truck is examined for suitability as an infantry personnel and cargo carrier.

In addition, weapon kit adaptations are given close examination to determine potential of the truck as a weapons carrier. Again, endurance and reliability data accumulated under slightly different tactical conditions are added to the overall data bank.

Prototype 7 undergoes a similar type of application test phase at the U.S. Army Artillery Board, Fort Sill, Oklahoma. Here, however, the test is artillery oriented. Ammunition loads of all calibers are examined for ease of loading, adequacy of tie-downs, and stability of load during road and cross-country operations. Further, the truck is examined as a prime mover for prescribed towed artillery.

Prototype 7 is next delivered to the General Equipment Test Agency, Fort Lee, Virginia, for movement adaptability and logistics-over-the-shore tests. These tests are directed toward determining:

1. Capability of the truck to be shipped or transported by all modes of transportation (highway, rail, and water).



Fig. 8 - Swimming tests

2. Capability of the truck to operate from ship to shore in beach landing operations, on and off the ramps of various landing craft, and over the beach through sand, dunes, and marsh (Fig. 9).

3. Capability of the item to serve as a logistical carrier in "line haul" operations.

Prototype 7 is then shipped to the Tropic Test Center, Fort Clayton, Panama Canal Zone, for tropic tests. Testing in the tropics is oriented toward:

1. Determining vehicle mobility under adverse terrain conditions caused by heavy rainfall (up to 21 in. per month) including mud and dense surface vegetation (Fig. 10).

2. Resistance of the vehicle and its components to biotic growth under sustained high temperature and moisture conditions.

3. The heavy rain season in Panama lasts from July through November, but humidity remains almost constant (Table 3). Year-round tests are desired to gain meaningful data on biotic growth, to study mobility problems in the high Savannah

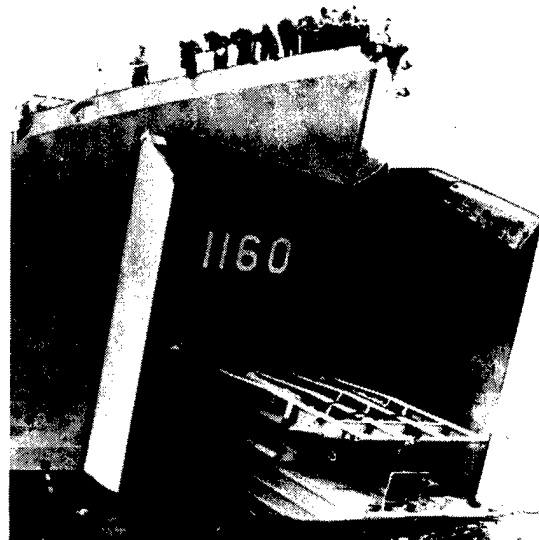


Fig. 9 - Embarking from landing craft



Fig. 10 - Tropic mud operation

grass areas, and to accumulate durability and reliability mileage under tropical terrain conditions.

Prototype 8, the last prototype, undergoes desert tests at Yuma Proving Ground, Yuma, Arizona. These tests are normally of both an engineering and service nature, with primary objectives of determining:

1. Cooling characteristics of the test truck under summer, high temperature conditions (Table 4).
2. Vapor handling characteristics of the fuel system under both full load and road load conditions.
3. Dust handling characteristics of air cleaners (Fig. 11).
4. Operational characteristics of the test vehicle at land elevations up to 8000 ft.

Table 3 - Canal Zone Environment (2)

Month	Mean Temperature, F	Mean Relative Humidity, %	Mean Precipitation, in.
Jan.	80	78	3.4
Feb.	80	77	1.5
Mar.	81	77	1.5
Apr.	82	79	4.1
May	81	83	12.5
June	81	85	13.9
July	81	86	15.6
Aug.	81	86	15.3
Sept.	81	85	12.8
Oct.	80	85	15.8
Nov.	80	86	22.3
Dec.	80	82	11.7

Table 4 - Yuma Proving Ground Environment (3)

Month	Temperature, F (mean maximum)	Mean Daily Solar Radiation, langleys/ minute*	Mean Precipitation, in.
Jan.	67	--	0.39
Feb.	72	--	0.41
Mar.	79	--	0.32
Apr.	86	--	0.09
May	93	0.88	0.03
June	102	0.92	0.01
July	106	0.90	0.19
Aug.	103	0.83	0.57
Sept.	100	0.80	0.40
Oct.	87	--	0.27
Nov.	76	--	0.23
Dec.	67	--	0.47

*1 langley/minute = 221.214 Btu/ft²/hr.

5. Mobility over desert terrain, including sand dunes, plains, and slopes, dry rocky stream beds, volcanic ash and stony desert (Fig. 12).

6. Durability and reliability under hot, desert terrain conditions.

While not specified in the brief test coverage given for each phase of testing outlined above, at each test site attention is given to:

1. Environmental effects on crew and machine.
2. Acceptability of the weapon and vehicle kits (such as enclosures, radios, and high output generators) under extreme conditions.
3. Measures to facilitate and improve driver vision, crew comfort, maintenance, and parts life.

TEST TIME

Notice in Fig. 2 that tests have been scheduled for completion by all test agencies approximately one year after receipt of prototypes. One year, including reporting, is a representative test time on new major items of equipment. Time to test is always challenged. "Why does it take so



Fig. 11 - Dust environment of desert

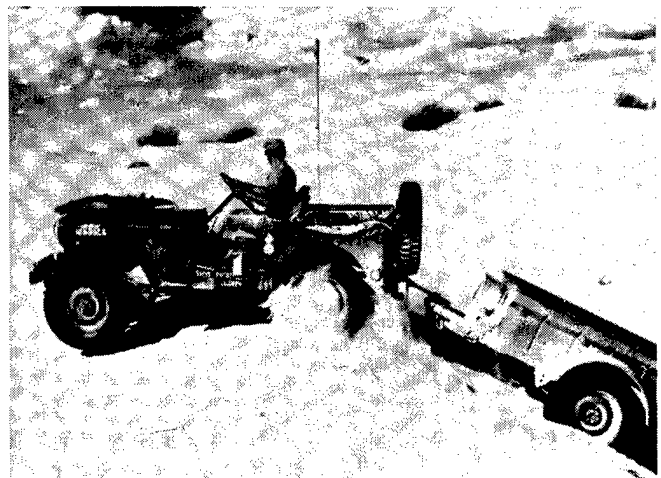


Fig. 12 - Sand dune operation

long?" is an ever present question. To properly discuss testing time would require a separate paper, but it seems essential to highlight some of the major influences.

To begin with, it is not possible to accomplish the extreme cold (arctic) and the extreme hot (desert) tests in less than one year, simply because the tests are seasonal -- six months apart.

Secondly, how long it takes to test is largely a matter of how well the designer has done his job. Experience has shown that, for the average vehicle, 1 hr of shop time (down-time for unscheduled maintenance and repair) is required for every operational hour. So, it is not a matter of driving time alone but also of the total time required to drive and maintain the vehicle over the 20,000 mile period.

Third, it is not possible because of limitations in numbers of test personnel to accomplish all testing on a crash or expedited basis. The normal test is accomplished on a single shift basis; expedited tests are on two shifts -- six days a week. Crash programs, in cases of extreme urgency, are on three shifts -- seven days a week. "Crashing" leads to mistakes on the part of operators and precludes good failure isolation and analysis.

Further, 24 hr operation is not realistic because components never cool down, acids and rust cannot form, and normal deterioration is not observed.

Other factors that govern test time include number of kits tested, complexity of vehicle design, uniqueness of design requiring new test procedures, vehicle speed and mobility, weather conditions, and spare parts support received.

REPORTING

Three principal types of reports are prepared during the course of testing. "Equipment Failure Reports" are single page reports issued by test agencies within 72 hr after failures occur. The purpose of the EFR is to keep all participating agencies (whether it be the designer, another tester, or project manager) fully informed about problem areas so that corrective actions can be initiated.

The report attempts to identify clearly the failed component, conditions of test under which the item failed, mileage or hours of operation on the part, and analysis of the failure as to cause. When possible, it includes a suggested course of redesign action.

"Interim Reports" are periodic reports published to provide "test status" information in greater detail than possible with the equipment failure report. These reports provide detail on test progress and may serve to transmit laboratory reports, photographs, sketches, and similar data.

"Final Reports" are published by each test agency at the completion of testing, and serve as the official documentary product of testing. The final test report includes the

purpose, procedures used, and results of each test phase. Each conclusion drawn is supported by test data. Recommendations for subsequent courses of development action must follow the detailed findings and conclusions.

The present reporting system offers several major advantages over former systems:

1. All test agencies are required to report against each item of the military characteristics, thus giving a measure of uniformity to the reports.
2. Reporting against military characteristics requires presentation of positive as well as negative performance data. That is, desirable features of the vehicular design are reported as well as deficiencies and shortcomings.
3. Since all reports are forwarded to TECOM at approximately the same time, results are consolidated at one level, avoiding divergent conclusions and recommendations as to suitability for Army use.

SUMMARY

Army testing has been consolidated under the direction of one organization, the U.S. Army Test and Evaluation Command.

The purpose of TECOM is to provide the Army with a sound, objective, and timely test program on all new materiel.

The scope of testing remains comprehensive, however, and by proper coordination, unnecessary duplication and unrealistic testing is being eliminated.

Test planning, execution, and reporting is being accomplished against military and technical requirements established for the vehicle design, thus ensuring objective and meaningful evaluation of test results.

When following a jet aircraft, you must look ahead of its sound, and this principle applies to the test planning now being accomplished by the Test and Evaluation Command, which will produce improved test programs and materiel in the future.

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